VICARIOUS CALIBRATION SITE SELECTION FOR RAZAKSAT™ MEDIUM-SIZED APERTURE CAMERA (MAC)

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ABSTRACT:

RazakSAT™ Medium-sized Aperture Camera (MAC) will be Malaysia's first calibrated earth observation satellite. Vicarious calibration is crucial to ensure the data quality of RazakSAT™ MAC since it carries no onboard calibrator. RazakSAT™ MAC's low inclination (9^o) orbit is in the near-equatorial region and thus, commonly used vicarious calibration sites such as deserts, dry lakebeds, playas, etc are not accessible. The main objective of this study is to determine the optimum sites, consisting of either natural and/or artificial targets, for the vicarious calibration of RazakSAT™ MAC. The criteria for the selection are based on a list of desired characteristics for a reflectance-based vicarious calibration approach from previous works by other researchers. RazakSAT™ MAC has a spatial resolution of 2.5m and 5.0m for panchromatic and multispectral band respectively. Studies found that chosen sites have to be larger than 15mx15m in size, which is equivalent to the 3x3 pixels requirement of RazakSAT™ MAC's spatial resolution. The suitability of determined targets and sites were assessed based on their reflectance and homogeneity using a field spectroradiometer. The optimal natural targets determined from this study's analyses are fine sand and small rocks, and optimal artificial target is tarpaulin. The sand and rocks have reflectance values greater than 0.4 while the tarpaulin's reflectance is greater than 0.7, adequate for calibration of all RazakSAT™ MAC bands. Furthermore, all these three targets are very homogeneous with almost constant spectral curves.

1. INTRODUCTION

RazakSAT™ is a small, earth-observation satellite to be launched into the near-equatorial orbit (NEqO) with an altitude of 685km and an inclination of 9°. Its electro-optical payload is the Medium-sized Aperture Camera (MAC). The MAC is a pushbroom imager with five linear coupled-charge device (CCD) detectors: one panchromatic band (510-730nm) and four multispectral bands (450-890). The four multispectral bands are Blue Band (450-520nm), Green Band (520-600nm), Red Band (630-690nm) and Near Infra-red Band (760-890nm). It is a high resolution imaging system with a ground sampling distance of 2.5m for the panchromatic band and 5m for the multispectral bands.

Since RazakSAT™ carries no onboard calibrator, post-launch vicarious calibration is a crucial activity to ensure data quality and integrity. Vicarious calibration refers to any approach that does not rely on an onboard calibration (Thome, 2002). Natural or man-made targets on the Earth surface can be used as ground calibrator. For vicarious calibration, common ground targets and test sites include deserts, dry lakebeds, playas, etc (Thome, 2002). Unfortunately, none of these exist in the equatorial region accessible by RazakSAT™'s orbit.

Hence, the main objective of this study was to identify optimal targets in Peninsular Malaysia to be used in the vicarious calibration of MAC, particularly for radiometric calibration. The vicarious calibration approach adopted in this study is the reflectance-based method.

In this approach, ground-based surface reflectance measurement of target is made simultaneously with satellite overpass. At the same time, the atmosphere is characterized. These data will then be input into a radiative transfer code to derive calibration coefficients (Thome, 2002).

However, the full-fledged calibration activities were not undertaken but the required criteria for the ground target surface reflectance measurement was adopted for the selection of calibration target and test sites. The optimality of determined targets and sites were assessed using a field spectroradiometer.

2. MATERIALS AND METHOD

There are four main stages in this study. Firstly, previous works on vicarious calibration were reviewed and list of criteria of calibration targets and test sites were compiled. Then, Satellite Tool Kit (STK) software was used to generate a simulated flight path of RazakSAT™ over Peninsular Malaysia. Potential targets and sites from areas that were covered by the flight path and fulfilled the criteria listed were chosen for further assessment. Next, a spectroradiometer was used to obtain spectra readings of the chosen targets and sites. Lastly, the spectroradiometer readings were assessed based on two main criteria: reflectance and homogeneity, to determine the optimal target/site. The optimal targets must have surface reflectance of greater than 0.3 and the spectral curves must be almost constant over repetitive readings to be homogeneous.

2.1 Criteria of Calibration Targets and Sites

Ground targets refer to the ground features, either natural or man-made, that would be used as a calibrator. Test sites refer to the location of these targets. Based on previous works, a list of desired characteristics of vicarious calibration targets and sites has been identified. The critical characteristics include: (i) high reflectance (greater than 0.3), (ii) high elevation, (iii) near Lambertian surface, (iv) spatial uniformity, (v) spectral homogeneity, (vi) arid region, (vii) minimal seasonal changes, and (viii) accessibility (Thome, 1999 and Kneubühler *et al,* 2003). In this study, criteria (ii) and (vi) were not used to assess the optimality of targets.

2.2 Selection of Potential Targets and Sites

The Satellite Tool Kit (STK*[*]) software was used to simulate the flight path of RazakSAT™ over Malaysia. Test sites must be within the swath of RazakSAT™. From the test sites, potential targets were analyzed based on how well the targets met the criteria requirements.

Due to logistics and financial constraints for this study, only three sites were selected for further assessment using the spectroradiometer. These three sites are: (i) UTM Skudai campus, (ii) Bukit Jalil Stadium, and (iii) a quarry in Puchong. Potential targets were then selected from within the three sites. The targets selected based on the set criteria were as followed:

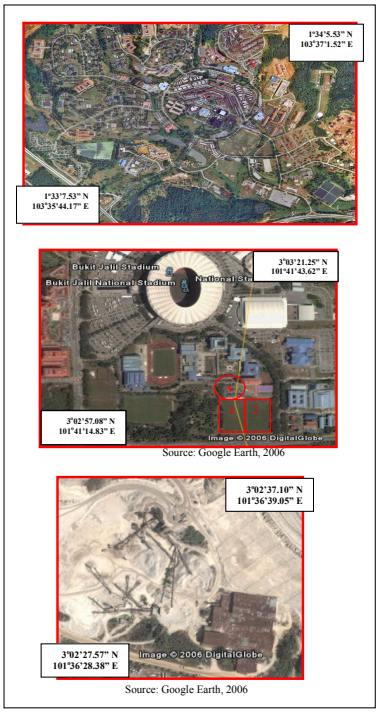

Figure 1: Selected Targets within Selected Sites

[*] STK is a trademark of Analytical Graphics, Inc. It is commercial-off-the-shelf analysis software for land, sea, air and space. It can support all phases of a satellite system life's cycle. (http://www.agi.com/products/desktopApp/stkFamily/modules/core/stk/, 3 May 2006)

2.3 Spectroradiometer Measurements

The spectroradiometer was used to obtain surface reflectance measurements of selected targets. It must be calibrated using the Spectralon panel before and after each target measurement and the readings must be constant. Any difference in the readings, delta, is gain by external factors such as transmittance and irradiance. The target spectra reading must be offset by the delta value.

In this study, the readings of the same location were repeatedly collected for a total of ten times and then averaged into one reading to represent that particular location. Six locations from each target area will be measured. All measurements were obtained from 450nm to 890nm to correspond to the spectral range of RazakSAT™ MAC.

2.4 Assessment Using Spectroradiometer Readings

Two major criteria to be assessed using spectroradiometer measurements are: (i) reflectance and (ii) homogeneity. Targets must have reflectance greater than 0.3. For the homogeneity criterion, the spectral curves of all six locations at each target must be similar if not constant. Homogeneous targets should have similar trends and values.

3.0 RESULTS, ANALYSES AND DISCUSSION

There are six different types of targets identified based on the list of desired characteristics. Three are natural targets: (i) grass, (ii) sand and rocks, (iii) water body while the remaining three are artificial targets: (a) tarmac, (b) cement and (c) tarpaulin.

The spectroradiometer measurements are shown in the following graphs. Assessments based on the spectroradiometer readings were also performed to determine the most optimal targets.

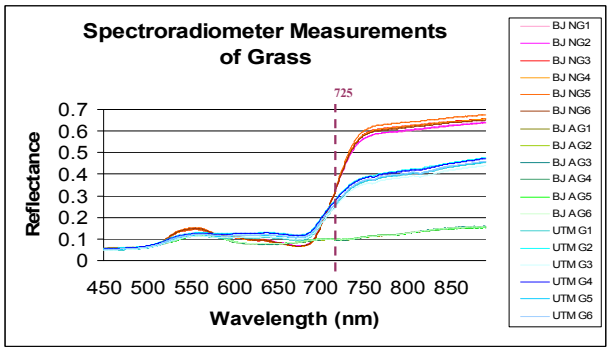

Figure 2: Spectroradiometer Measurements of Grass

In Bukit Jalil Football Field, spectroradiometer measurements were collected from two types of grass, natural (BJ NG) and artificial (BJ AG). Another set of measurements were obtained from UTM Football Field. From the graph above, it is seen that the artificial grass is not a suitable target. The natural grass, however, is suitable for RazakSAT™ Band 4 calibration due to its high reflectance (greater than 0.3) in the 725nm wavelength. The spectral curves are rather similar, thus homogeneous.

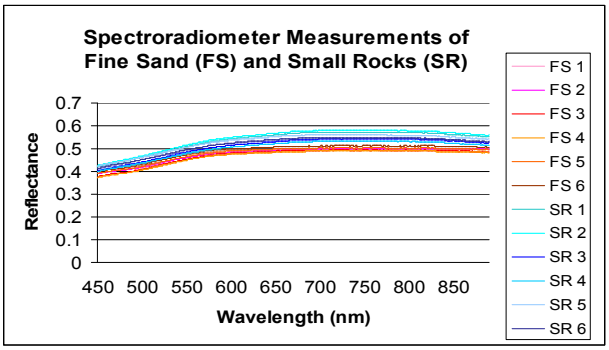

Figure 3: Spectroradiometer Measurements of Fine Sand and Small Rocks

Both the fine sand and small rocks have reflectance greater than 0.3. Similarities in spectral curves indicate homogeneity. These two are optimal targets.

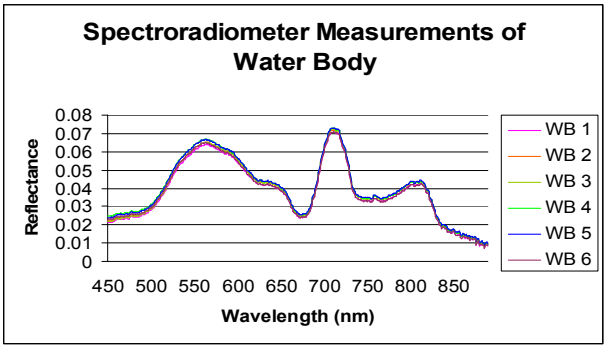

Figure 4: Spectroradiometer Measurements of Water Body

The water body spectra were collected from UTM Lake. It is evident that the reflectance is very low although the surface is very homogeneous. Therefore, it is not a good calibration target.

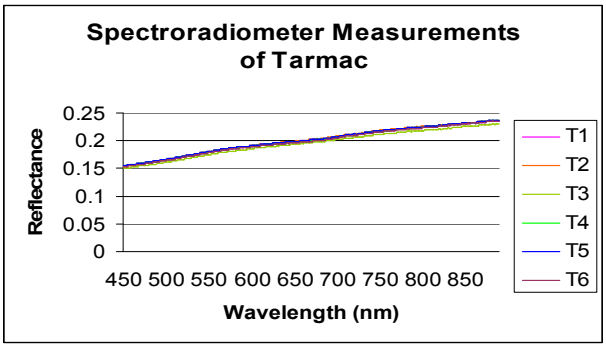

Figure 5: Spectroradiometer Measurements of Tarmac

Tarmac is a very homogeneous target but has very low reflectance (less than 0.3). Thus, it is not a desirable calibration target.

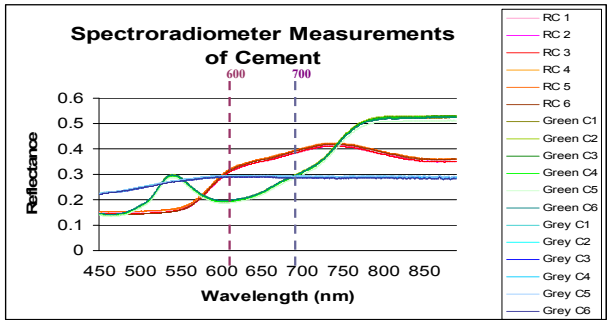

Figure 6: Spectroradiometer Measurements of Cement

Three types of cement were studied: red cement, green cement and grey cement. From the graph above, it can be seen all three surfaces are homogeneous. However, grey cement reflectance is still less than 0.3. The red cement exceeded 0.3 after 600nm which corresponds to Band 3 of RazakSAT™ MAC. The green cement is greater than 0.3 after 700nm, which is suitable for Band 4 calibration.

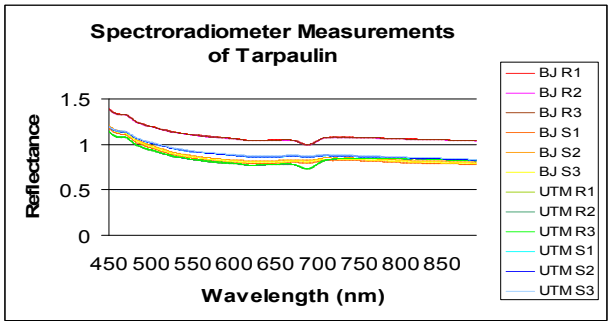

Figure 7: Spectroradiometer Measurements of Tarpaulin

Spectroradiometer measurements were collected for both the rough (R) and smooth (S) surfaces of the tarpaulin, in Bukit Jalil (BJ) and UTM Skudai (UTM). The spectral curves for each surface and location measurements were constant. The reflectance value is also very high. Therefore, tarpaulin is an optimal target.

From the spectroradiometer measurements, it was found that natural grass, green and red cement, fine sand and small rocks, as well as tarpaulins will make a good calibration target. However, good targets are not necessarily optimal. Firstly, the target must also fulfill the spatial uniformity criterion (3x3 pixels). This means that the calibration target area must be at least 15mX15m. Due to this criterion, the green and red cement which were found in basketball and tennis courts are not optimal targets. A basketball court is 28m x 15m and a tennis court is 24m x 11m. Even though the basketball court has a width of 15m which could be sufficient to provide spatial uniformity, the lines on the court reduces the spectral homogeneity of the target. Therefore, the green and red cement could not be used as a calibration target.

Secondly, the RazakSAT™ has a total of four spectral bands. Some of the targets are only suitable to calibrate certain band only. The natural grass and green cement targets only exceed the desired 0.3 reflectance from the 725nm and 720nm wavelength onwards respectively. This means that both these targets are only suitable for Band 4 calibration. Similarly, the red cement exceeds

the desired 0.3 reflectance from 600nm onwards. This target is suitable to calibrate the Band 3 and Band 4 only.

Finally, only the fine sand, small rocks and tarpaulin are the most optimal targets. These targets fulfilled the high reflectance and homogeneity criteria the best. The summary of the assessment results of the studied targets and set criteria is shown in Appendix 1.

4.0 CONCLUSION

In conclusion, the optimal targets for vicarious calibration in Peninsular Malaysia are fine sand, small rocks and tarpaulins. Fine sand and small rocks can be found in quarries. Tarpaulin is a very flexible target as it can be put anywhere. However, the best site to place a tarpaulin is in a stadium. This is due to the size of the tarpaulin (15mx15m) and there is a large piece of grassland in the stadium that can also serve as a natural calibrator.

5.0 REFERENCES

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6.0 APPENDIX

Target / Criteria	Natural Grass	Artificial Grass	Tarmac	Grey Cement	Green Cement	Red Cement	Fine Sand	Small Rocks	Water Body	Tarpaulin
High Reflectance (>0.3)	Band 4	No	No	No	Band 4	Band 3, Band 4	All Bands	All Bands	No	All Bands
Near Lambertian Surface	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spatial Uniformity (3x3 pixels)	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Spectral Homogeneity and Blandness	Yes	Yes	Yes	No	No	No	Yes	Yes	No	Yes
Minimal Seasonal Changes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Accessibility	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Conclusion	**Good Target**	**Bad Target**	**Bad Target**	**Bad Target**	**Bad Target**	**Bad Target**	**Optimal Target**	**Optimal Target**	**Bad Target**	**Optimal Target**

Appendix 1: Assessment Results of Studied Targets and Desired Characteristics